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ABSTRACT

Reported are the results of a meta-analysis of 30 studies of individualized instruction in science in which this method was compared with a traditional lecture method of science instruction. Studies analyzed also included measurements from which effect sizes could be calculated. Five methods of individualized instruction were identified: (1) audio-tutorial instruction (AT), (2) computer-assisted instruction (CAI), (3) personalized system of instruction (PSI), (4) programmed instruction (PI), and (5) a combination category for studies containing characteristics of individualization but not easily identifiable as one of the previous four methods. On the basis of effect size, individualized instruction appeared to be more effective than the traditional lecture approach for all methods studied. Findings reported were termed preliminary indicating this study was not completed when reported. (PB)

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A Meta-Analysis of Individualized Instruction in Science*

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*This paper was prepared for presentation at the annual meeting of the American Educational Research Association, Boston, April 7 - 11, 1980.

Introduction

During the past twenty years many educational researchers have evaluated the effectiveness of individualized instruction in science. These investigations have resulted in the publication of numerous studies, often contradictory in their conclusions. A review and integration of this existing research brings meaning to a large collection of experiments which would otherwise be difficult to interpret collectively.

There are numerous narrative reviews of research on alternative methods of instruction. Meta-analysis, the statistical integration and analysis of research studies, has been employed in a few instances (Dubin & Taveggia, 1968; Hartley, 1978; Kulik, Kulik & Cohen, 1979). The purpose of this study was to determine whether individualized instruction in science is more effective than traditional science instruction based upon a meta-analysis of findings from previous research experiments.

The methods of individualized instruction incorporated in this study were audio-tutorial instruction, computer-assisted instruction, personalized system of instruction, and programmed instruction. Instruction involving assorted elements of the previously listed methods were included under a heading reflecting a combination approach. For the purpose of this study, the methods of individualized instruction were defined as follows:

Audio-tutorial instruction (AT) is an instructional method developed by Postlethwait (1963) involving three main components. The Independent Study Session is the primary activity in audio-tutorial instruction. Students work independently in a learning center equipped with laboratory materials, audio tapes and visual aids. The Small Assembly Session is a weekly meeting of six to ten students and an instructor for the purpose of discussion and quizzing. A weekly meeting, the General Assembly Session,

is used for motivational lectures, films and major examinations. Computer-assisted Instruction (CAI) involves the use of a computer in an interactive fashion. Programmed instruction, drill and practice, and/or tutorial exercises are frequently implemented in CAI. The Personalized System of Instruction (PSI) was first described by Keller (1968) and has frequently been termed the Keller Plan. PSI involves the following components: 1) printed study guides, 2) mastery orientation, 3) student proctors, 4) self-pacing, and 5) occasional lectures for motivation. Programmed Instruction (PI) is the presentation of instruction in a step by step sequential manner. It is a procedure employed in many types of individualized instructional methods. For the purpose of this meta-analysis, programmed instruction involved information dissemination which was programmed and in a written format. Studies containing characteristics of individualization, not easily identified as one of the above methods, were grouped into a Combination category. The courses frequently contained a study guide, objectives, pretests and posttests.

Methodology

This study of alternative methods of teaching science courses consisted of a literature search for research findings comparing one or more individualized methods of science instruction with traditional lecture instruction, a subsequent review of this literature, and the selection of studies to be analyzed. The analysis involved the comparison of effect sizes and their relationship to other variables reported in the research studies. The major goals of this meta-analysis were to reach a conclusion about the experimental effect of individualized instruction in science and to attempt to explain the variation in the effect sizes obtained.

Literature Search

Documents incorporated in this study were identified in numerous ways. First, a computer search of the ERIC system was utilized. A total of 553 documents were initially identified; approximately 100 studies were selected for further review, of which approximately 30 were fully analyzed and incorporated into the meta-analysis. Second, a computer search of Dissertation Abstracts was utilized. This search identified 73 dissertations, of which 23 microfilm copies were selected for incorporation in the study. The bibliography of each of these studies was reviewed to identify additional research reports. Finally, recent issues of selected journals on science education were reviewed in search of recent research.

Once documents were identified, the following guidelines were used in determining which studies were to be included in the meta-analysis. First, only those studies comparing a traditional lecture method of science instruction with a method of individualized instruction were included. Second, in order to be included, a study had to include measurements from which "effect sizes" could be calculated. The quality of the research design did not eliminate a study from inclusion in the meta-analysis. Some researchers (Eysenik, 1978; Gallo, 1978; Mansfield, 1977) feel that only well-designed studies should be analyzed, whereas Glass (1976, 1978) contends that elimination of weaker studies excludes a lot of important and useful information. In this study all relevant research was included and features of the research design were identified and included as variables in the meta-analysis.

Within a given study, multiple outcomes were incorporated in the meta-analysis. Some previous research integrators avoided the use of

more than one measurement per study analyzed (Kulik, 1976; Dubin & Taveggia, 1968). Glass (1978) contends that much valuable information is discarded by eliminating multiple measurements and suggests that the "finding" be the unit of analysis, rather than the "study". In this meta-analysis the finding was the unit of analysis and consideration was given to the interdependence of various outcome measures. An attempt was made to exclude findings based on repeated measures of the same latent trait. The measurement related to the longest treatment time was the outcome selected for inclusion. If a number of equally viable, but interdependent outcome measures were indicated, a random selection was made.

Data Collection and Analysis

Each study was carefully read and information collected on numerous variables. Table 1 contains a list of variables and coding categories included in this study and an indication of the number of studies and effect sizes included in each category. A total of 115 studies were analyzed and 182 effect sizes calculated.

Effect sizes were calculated using Cohen's *d* (Cohen, 1969) and Glass's *ES* (Glass, 1978). Cohen's *d* is the difference in the means of the two groups divided by the pooled standard deviation. Glass's *ES* is the difference in the means of the two groups divided by the standard deviation of the control group, which in this meta-analysis was the group taught in the traditional manner.

$$\text{Effect size} = \frac{\bar{X}_E - \bar{X}_C}{s_c \text{ or } s_p}$$

where: $\bar{X}_E$ = mean of individualized instruction group

$\bar{X}_C$ = mean of traditionally taught group

s_c = standard deviation of traditionally taught group

s_p = pooled standard deviation

Studies which did not indicate the required measurements for the calculation of effect sizes (i.e. $\bar{X}_E$, $\bar{X}_C$, s_c or s_p) were included in the meta-analysis and effect size measures approximated using procedures described by Glass (1978). When results were presented in dichotomies or percentages, an attempt was made to recover underlying metric information by the use of the differences of the standard normal deviates (Glass, 1978). Effect sizes approximated in the above ways were considered to be calculated using pooled standard deviations.

One hundred fifteen effect sizes were calculated using Glass's ES and Cohen's d. The correlation between Glass's ES and Cohen's d was found to be .904. This high correlation, coupled with the fact that more estimates of effect sizes calculated as Cohen's d were available, resulted in a decision to use Cohen's d as the measure of effect size in this meta-analysis.

Results

One of the goals of this study was to determine the effect of individualization in science instruction. The mean effect size, based on 115 studies, was .35 which falls within the range of small effect sizes (0 to .5) according to Cohen (1969). The effect of individualized

instruction in science, in other words, was an increase of .35 standard deviations in measurable outcomes. The mean (50th percentile) for a class taught using individualized instruction would, therefore, be equal to the 64th percentile (+.35 standard deviation) of an otherwise equivalent class taught in a traditional lecture format.

Effect sizes were calculated for each method of individualized instruction. Table 2 shows the effect sizes for the five methods of individualized instruction investigated. The studies classified as combination had the greatest effect, followed closely by computer-assisted instruction and PSI. These three instructional methods had effect sizes approaching a medium size effect as defined by Cohen (.5 to .8). Audio-tutorial instruction and programmed instruction had the smallest effect sizes.

A comparison was made of the effect sizes derived for each variable investigated in the meta-analysis by instructional method. These comparisons are included in Tables 3, 4, and 5.

A number of variables appear to have an impact on effect sizes for all instructional methods. Variables related to the degree or manner of individualization of instruction, as well as some variables reflecting research design characteristics appear correlated with effect size.

The differences in subpopulation means within each of four instructional and three design variables were tested at the .05 level using t-tests and analysis of variance. Within two of the design variables, the equivalence of subjects and the subjective rating by the meta-analyst, significant differences were found among the means. In addition, significant differences were found between the subpopulation effect size means within two instructional variables, mastery orientation

and the degree of self-pacing of instruction. No significant differences were found, however, between the subpopulation effect size means for self-selection of treatment, self-initiated testing, and choice of delivery system.

The next question addresses the identification of the instructional and design variables which account for the variance in effect size. Our results, while only preliminary, suggest that neither set of variables explains very much of the variance in effect size. When effect size was regressed on sets of dichotomously coded dummy variables measuring variation in instruction and design variables (see a list of these in Table 1), the coefficients of determination were .07 and .14, respectively, for the instructional and design variables. These results are shown in Tables 6 and 7. Among the design variables, those studies we rated as excellent exhibited effect sizes of one-half standard deviation larger than studies that were not coded as being excellent. Also, if the subjects were self-selected into the treatment group, the effect size was about one-third larger than in studies where subjects were randomly assigned.

In conclusion, we conducted a meta-analysis of individualized instruction in science and found, on the basis of effect size, that individualized instruction is more effective than the traditional lecture approach.. This is true for all methods of individualized instruction studied. Although our study has not been completed, it appears that computer-assisted instruction (CAI) and the personalized system of instruction (PSI) are more effective than audio-tutorial (AT) and programmed instruction (PI).

We identified and incorporated design and instructional variables within the meta-analysis. There is a significant difference in the mean

effect sizes within a few of these variables. However, our initial attempts at explaining the variance observed in effect sizes using multiple regression analysis has failed to identify any instructional or design variables which account for a large portion of the variance in effect size. This preliminary finding suggests that differences observed between individualized and traditionally taught students may be a function of the presence of alternatives for the students and not the alternatives themselves.

TABLE 1

List of Variables with Number of Studies and Effect Sizes for Coding Categories

Variable	Number of Studies	Number of Effect Sizes
Source of study		
1. Journal	38	53
2. Document	8	14
3. Dissertation	65	110
4. Book	4	5
Year of publication		
1961	1	3
1963	4	5
1964	4	4
1965	3	5
1966	2	3
1967	2	3
1968	4	9
1969	8	9
1970	13	24
1971	11	17
1972	13	18
1973	12	19
1974	11	15
1975	11	21
1976	10	14
1977	5	10
1978	1	3
Instructional setting		
1. Secondary school	34	59
2. Community College	12	20
3. Four year school	67	74
4. Other	2	2
Subject of instruction		
1. Biology	40	60
2. Chemistry	37	58
3. Physics	20	37
4. Other	18	27
Level of instruction		
1. Introductory	100	162
2. Advanced	14	19

TABLE 1 (continued)

Variable	Number of Studies	Number of Effect Sizes
Method of instruction		
1. Audio-tutorial (AT)	27	40
2. Computer-assisted (CAI)	11	14
3. Personalized System of Instruction (PSI)	19	28
4. Programmed Instruction (PI)	28	45
5. Combination	30	56
Nature of instruction		
1. Replacement of existing instruction	101	166
2. Supplement for existing instruction	13	15
Number of weeks of instruction	105	163
Mastery orientation		
1. Non-mastery	83	130
2. Mastery	28	43
Self-initiated testing		
1. Self-initiated testing present	38	65
2. No self-initiated testing	74	113
Self-pacing of instruction		
1. Daily	19	33
2. Weekly	44	62
3. Longer period than weekly	9	16
4. Entire course self-paced	41	69
Choice of instructional delivery systems		
1. No choice	89	138
2. Choice	26	43
Outcomes measure		
1. Achievement	110	114
2. Attitude	22	27
3. Retention	19	22
4. Study time	1	1
5. Performance in subsequent courses	3	5
6. Others	9	13

TABLE 1 (continued)

Variable	Number of Studies	Number of Effect Sizes
Subjective rating by meta-analyst		
1. Excellent	6	15
2. Good	35	58
3. Fair	42	65
4. Poor	30	41
Instrument development		
1. Teacher developed	59	80
2. Team developed	19	26
3. Commercially available	31	48
Historical effect		
1. Same semesters	97	115
2. Different semesters	18	26
Continuity of instructors		
1. Same instructors	51	76
2. Different instructors	54	86
Self-selection of treatment		
1. Yes	22	34
2. No	87	139
Equivalence of subjects		
1. Absent	21	30
2. One measure	18	30
3. 2-4+ measures	21	32
4. Randomization	32	53
5. Covariates	20	30
Reliability of instrument	49	74

TABLE 2

Effect Sizes of Instructional Methods

Method of Instruction	Effect Size	Number of Studies	Number of Effect Sizes
Audio-tutorial	.21	27	40
Computer assisted	.42	11	14
Personalized system of instruction	.42	19	28
Programmed instruction	.27	28	45
Combination	.47	30	56
Total	.35	115	182

TABLE 3 - Effect Sizes for Instructional Methods by Instructional Variables

VARIABLES	TOTAL			AT			CAI			PSI			PI			COMB		
	Effect size	S.D.	n	Effect size	S.D.	n	Effect size	S.D.	n	Effect size	S.D.	n	Effect size	S.D.	n	Effect size	S.D.	n
Mastery orientation																		
Nonmastery	.28	.48	129	.21	.36	38	.26	.73	10	.22	.51	2	.29	.42	41	.36	.56	38
Mastery	.53	.63	43	.09	0	1	1.06	.73	2	.43	.46	26	.52	0	1	.67	.91	13
Self-pacing of instruction																		
Daily	.26	.43	28	-.38	0	1	.46	.85	4	-	-	-	.24	.34	19	.28	.08	4
Longer	.33	.46	79	.23	.36	37	.35	.33	3	.77	.38	2	.39	.51	18	.41	.58	19
Entire course	.46	.69	68	.08	0	1	.45	1.00	5	.39	.46	26	.36	.12	4	.55	.84	32
Self-initiated testing																		
Yes	.46	.68	65	-	-	-	-.43	.01	2	.41	.47	27	.48	.24	6	.56	.87	30
No	.29	.46	112	.21	.36	39	.57	.69	11	.50	0	1	.23	.44	38	.37	.50	23
Choice of delivery system																		
No choice	.30	.47	138	.19	.35	38	.39	.79	11	.39	.45	27	.25	.44	41	.41	.51	21
Choice	.53	.75	43	.74	0	1	.58	.30	2	1.03	0	1	.43	.23	4	.51	.83	35

TABLE 4 - Effect Sizes for Instructional Methods by Design Variables

VARIABLES	TOTAL			AT			CAI			PSI			PI			COMB		
	Effect size	S.D.	n	Effect size	S.D.	n	Effect size	S.D.	n	Effect size	S.D.	n	Effect size	S.D.	n	Effect size	S.D.	n
Subjective rating of study																		
Excellent	1.08	.98	4	-	-	-	.79	0	1	1.10	1.57	2	-	-	-	.82	.90	12
Good	.35	.55	58	.36	.39	17	-.16	.45	3	.35	.14	6	.27	.27	7	.41	.74	25
Fair	.39	.44	64	.10	.31	17	.44	.73	5	.30	.31	13	.39	.46	17	.38	.50	12
Poor	.28	.50	41	.06	.20	5	.88	1.01	3	.50	.34	7	.17	.44	19	.25	.56	7
Instrument development																		
Teacher developed	.36	.58	80	.23	.42	18	.65	.67	7	.63	.63	10	.28	.41	28	.38	.81	17
Team developed	.45	.52	26	.48	.35	5	.36	0	1	.27	.40	7	.20	.62	7	.95	.41	6
Commercial	.28	.62	48	.01	.17	9	-.43	.01	2	.15	.15	4	.40	.40	3	.41	.72	30
Self-selection of treatment																		
Yes	.49	.59	34	.20	.40	11	1.07	.79	3	.38	.23	10	.60	.08	4	.84	1.03	6
No	.32	.54	139	.22	.35	27	.07	.44	9	.49	.57	15	.23	.43	40	.45	.68	48
Equivalence of subjects																		
Absent	.39	.50	30	.00	.03	3	1.07	.79	3	.39	.34	10	.52	.42	8	.07	.50	6
One measure	.08	.38	30	.00	.03	3	.21	.06	2	.25	.26	7	.00	.52	10	-	-	-
2-4+ measures	.34	.46	32	.41	.39	5	.63	.83	3	.49	.34	5	.17	.35	9	.28	.50	10
Randomization	.35	.52	53	.29	.41	17	-.01	.49	4	.80	.95	4	.19	.26	11	.50	.56	17
Covariates	.63	.80	30	.06	0	1	.79	0	1	.17	.26	2	.60	.32	5	.70	.93	21
Historical effect																		
Same semesters	.35	.56	115	.23	.38	33	.46	.75	12	.41	.47	26	.24	.41	42	.50	.74	42
Different semesters	.36	.56	26	.09	.26	6	-.03	0	1	.53	.28	2	.72	.39	3	.40	.68	14
Continuity of instructors																		
Same instructors	.33	.49	76	.15	.29	13	.39	.83	6	.43	.17	8	.44	.31	15	.32	.58	34
Different instructors	.33	.57	86	.24	.41	22	.39	.75	6	.50	.58	15	.15	.47	25	.53	.75	18

TABLE 5 - Effect Sizes for Instructional Methods by Miscellaneous Variables

VARIABLES	TOTAL			AT			CAI			PSI			PI			COMB		
	Effect size	S.D.	n	Effect size	S.D.	n	Effect size	S.D.	n	Effect size	S.D.	n	Effect size	S.D.	n	Effect size	S.D.	n
Source of information																		
Journal	.38	.51	52	.38	.44	16	.41	1.13	4	.47	.26	15	.13	.59	10	.54	.52	7
Document	.47	.82	14	.13	.15	3	.33	.76	5	-	-	-	.24	.02	2	1.02	1.24	4
Dissertation	.32	.55	110	.08	.26	20	.53	.25	4	-	-	-	.31	.38	33	.41	.69	45
Book	.40	.33	5	-	-	-	-	-	-	.40	.33	5	-	-	-	-	-	-
Setting of study																		
Secondary school	.25	.48	57	-.38	0	1	.08	.60	4	-	-	-	.24	.40	23	.30	.52	29
Community college	.40	.56	20	.18	.35	10	-	-	-	.89	1.17	3	.43	.25	4	.60	.57	3
4 yr institution	.41	.60	100	.26	.36	26	.57	.76	9	.36	.30	25	.26	.50	18	.70	.93	22
Level of instruction																		
Introductory	.32	.53	161	.16	.36	33	.47	.83	10	.44	.49	24	.26	.42	43	.40	.64	51
Advanced	.56	.71	19	.45	.30	6	.26	.28	3	.30	.16	4	-.18	0	1	1.24	1.12	5
Subject of instruction																		
Biology	.30	.44	59	.19	.37	30	.36	0	1	.64	.24	3	.21	.40	11	.54	.55	14
Chemistry	.36	.64	58	.24	.43	3	.52	.88	8	.63	.75	7	.25	.43	21	.32	.73	19
Physics	.41	.61	37	.27	.37	5	.23	.52	4	.35	.26	13	-.03	.48	3	.72	.89	12
Other	.37	.54	27	.37	0	1	-	-	-	.17	.36	5	.47	.41	10	.38	.72	11
Nature of instruction																		
Replacement	.35	.55	165	.21	.36	39	.05	.53	5	.42	.46	28	.28	.43	37	.47	.72	56
Supplement	.39	.65	15	-	-	-	.65	.78	8	-	-	-	.09	.32	7	-	-	-

TABLE 6

Regression Results of Design Variables

Variable	B	Beta
Rating = Excellent	.567	.282
Rating = Good	.031	.026
Rating = Fair	-.032	-.027
Self Selection	.302	.213
Equivalence is absent	-.040	-.027
Equivalence on one meas.	-.286	-.192
Equivalence on 2-4+ meas.	.037	.025
Randomization	.026	.021
Constant	.289	

TABLE 7

Regression Results of Instructional Variables

Variable	B	Beta
Mastery	-.228	-.185
Choice of Delivery	-.209	-.160
Pace = Weekly	.036	.032
Pace = Daily	.005	.003
Self-testing	.031	.027
Constant	.645	

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